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Spectroscopic Investigation of TW Dra: Improved Stellar and System Parameters

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Abstract. We investigate the Algol-type system TW Dra by means of the new computer program Shellspec07_inverse which is specially designed for the fine-tuning of stellar and system parameters of eclipsing binaries. We derive precise atmospheric and system parameters of TW Dra with an accuracy comparable to that expected from photometric data, and give a short comparison of our results with previous determinations.

1. Introduction

TW Dra is a bright, short-period (P = $2^d.80685$) Algol-type system that is in turn the bright component of the visual binary ADS 9706. The star belongs to the class of oEA stars (Mkrtichian et al. 2004) - mass-accreting components of Algol-type systems exhibiting δ Scuti like oscillations. The primary eclipse is a total one and the star is by 2 mag fainter at this phase (Popper 1989). The most detailed study known so far was done by Zejda et al. (2010) where the authors determined stellar and system parameters based on both radial velocities and light curve. The short-term variability of TW Dra was first discovered by Kusakin et al. (2001). Kim et al. (2003) suggested that the star is a multi-periodic pulsator. The first attempt of spectroscopic mode identification was done by Lehmann et al. (2008) where the authors could limit the range in l and m to 7 to 12, but no unique identification has been found.

Observations used in this work were obtained with the Coude-Echelle-Spectrograph at the 2-m telescope at the Thüringer Landessternwarte Tautenburg (TLS) and with the BOES echelle-spectrograph at the 1.8-m telescope of the Bohyunsan Optical Astronomy Observatory (BOAO).

2. Spectroscopic modeling

The new computer program Shellspec07_inverse has been used to compute the composite synthetic spectra of TW Dra. It is based on the Fortran 77 code Shellspec07 written by Budaj & Richards (2004) and is specially designed to solve the inverse problem of finding stellar and system parameters of eclipsing binaries (EBs). Shellspec07_inverse provides us with an accuracy comparable to that expected from photometry. Instead of using one of the analytical laws usually used for the approximation of the limb darkening effect, Shellspec07_inverse directly computes the intensity spectra for different positions on the stellar surface. In case of gravity darkening, we use a library of intrinsic line profiles pre-calculated for different temperatures. The intrinsic spectrum at a certain point at the stellar surface is computed for the specific temperature given by the gravity darkening law by interpolating within this library.

For the optimization of stellar and system parameters we use a modified version of the Levenberg-Marquardt non-linear optimization algorithm developed by Piskunov & Kochukhov (2002).

3. Results

By using the Shellspec07_inverse code, we fine-tuned the stellar and system parameters of TW Dra based on a model that considers two stars where the secondary fills its Roche-lobe. The light contribution from the third, visual component strongly complicated the modeling, however. This contribution is unpredictable and depends on the slit orientation and seeing conditions during the observations. We solve the problem by means of a least-squares fit including the calculated and observed spectra of the Algol-type system and one observed spectrum of the visual component. Optimized stellar and system parameters of the TW Dra system are listed in Table 1. We also derived the projected rotational velocity of the primary, system γ-velocity, and RV semi-amplitudes of both components to $v \sin i$ = 49.9(2) km s^{-1}, γ = -0.8(1) km s^{-1}, K_1 = 64.0(2) km s^{-1} and K_2 = 156(1) km s^{-1}. Our model matches the observations well with χ^2 = 1.47 for spectra from 2007 and χ^2 = 1.77 for those from 2008. All parameters are in good agreement with the recent findings by Zejda et al. (2010) except for the effective temperature of the secondary which is of about 100 K larger in our case.

Table 1. Stellar and system parameters derived with Shellspec07_inverse. Errors of measurement in units of the last digit are given in parentheses.

T_1 (K)	T_2 (K)	$\log g_1$	$\log g_2$	R_1 ($R_\odot$)	M_1 ($M_\odot$)	M_2 ($M_\odot$)	q	a ($R_\odot$)	i (°)
8160(15)	4538(11)	3.88	3.25	2.58(2)	2.2(1)	0.90(5)	0.411(4)	12.2(2)	86.8(3)

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